University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Historical Research Bulletins of the Nebraska Agricultural Experiment Station (1913-1993)

Agricultural Research Division of IANR

4-1939

Further Studies of Selected Types of Domestic Gas Stoves

Arnold E. Baragar

Follow this and additional works at: http://digitalcommons.unl.edu/ardhistrb

Part of the Heat Transfer, Combustion Commons

Baragar, Arnold E., "Further Studies of Selected Types of Domestic Gas Stoves" (1939). *Historical Research Bulletins of the Nebraska Agricultural Experiment Station (1913-1993)*. 107.
http://digitalcommons.unl.edu/ardhistrb/107

This Article is brought to you for free and open access by the Agricultural Research Division of IANR at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Historical Research Bulletins of the Nebraska Agricultural Experiment Station (1913-1993) by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

COLLEGE OF AGRICULTURE UNIVERSITY OF NEBRASKA
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 111

Further Studies of Selected Types of Domestic Gas Stoves

Arnold E. Baragar
Department of Home Economics

LINCOLN, NEBRASKA
APRIL, 1939

LIBRARY
NEBRASKA WESLEYAN UNIVERSITY

COLLEGE OF AGRICULTURE UNIVERSITY OF NEBRASKA
AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 111

Further Studies of Selected Types of Domestic Gas Stoves

Arnold E. Baragar
Department of Home Economics

LINCOLN, NEBRASKA
APRIL, 1939

CONTENTS

Further Studies of Selected Types of Domestic Gas Stoves

ARNOLD E. BARAGAR

This bulletin is a supplement to Nebraska Agricultural Experiment Station Research Bulletin 86. Tests were conducted in the same manner as were those described in Bulletin 86; hence, no reference has been made to experimental methods unless a test has not been previously reported. This paper is primarily concerned with (1) a discussion of cooking tops producing excessive carbon-monoxide gas, (2) more data relative to cooking-top burner efficiencies, (3) a further discussion of automatic lighters, and (4) a detailed study of ovens.

COOKING TOPS AND OVENS STUDIED

The cooking tops for this study are shown in Figures 1 to 6. Five of them were of the enclosed type with either removable or fixed burner bowls. All of the tops followed the present trend towards small round burners. A noticeable change on these stoves was the tendency to bring the burners closer to the bottom of the pan, as one means of increasing the efficiency.

Stove N had a burner with an adjustable head so that the distance between the pan and burner could be varied to compensate for the difference in flame length between natural and manufactured gas.

Cooking tops K, L, and P were equipped with simmer burners. On tops K and P both the simmer burner and regular burner were lighted when the gas was on full. On stove L the simmer burner was not a part of the regular burner and simmer burners were furnished on the front burners only.

The ovens were fully insulated; the doors, side walls, back, and top had insulation which varied in thickness from ⅝ inch to 2 inches. Usually the back wall was the least insulated. The type of insulation varied from solid-block mineral wool to loosely packed mineral wool and blanket glass wool. All of the ovens were equipped with automatic heat controls. The doors were well fitted; that is, no large cracks were noticeable but they could not be considered as being tightly fitted.

Before any tests were made, the capacity of each cooking top and oven burner was computed from the total port area of the burner. Every gas burner is designed to burn a certain quantity of gas expressed in B.t.u. per hour. For domestic burners operating on either natural or manufactured gas the accepted capacity is 20,000 B.t.u. per square inch of port area. This knowledge was especially helpful in considering the oven burner, because a burner made for a larger capacity than was needed to heat the oven could not maintain a low oven temperature. In other words, the burner supplied too much heat when operated on the lowest flame possible. This knowledge of burner capacity also proved helpful in considering cooking tops which produced excessive carbon monoxide.

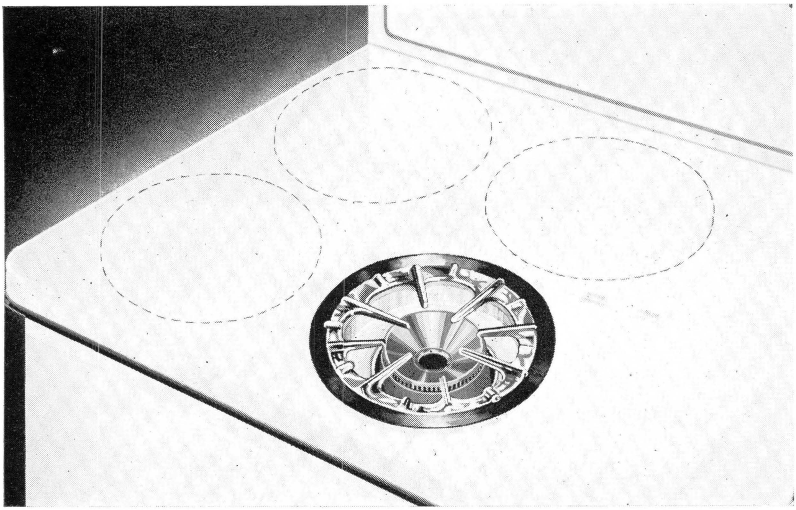

FIG. 1.—Burner assembly for cooking top K showing die-cast burner, burner bowl, and grate. The dotted lines indicate the positions of the other top burners.

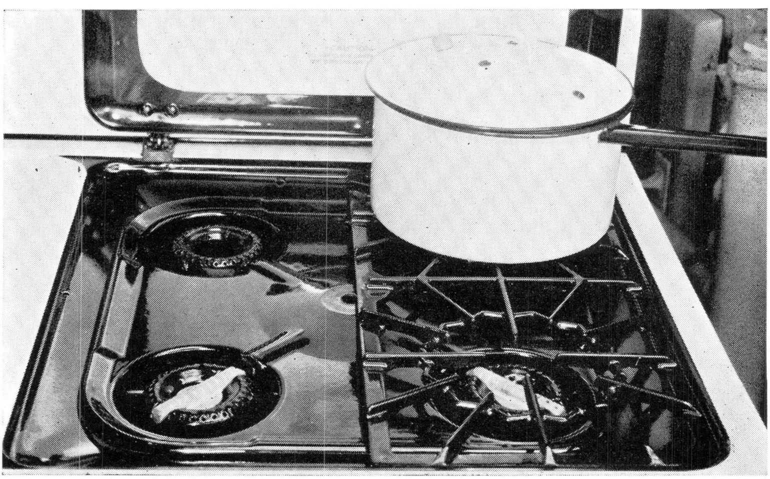

FIG. 2.—Cooking top L having cast iron circular burners with simmer burners in front; open grates and burner tray.

The port areas and capacities of top burners and oven burners and the interior volumes of the ovens are listed in Table 1. For actual operation, the quantity of gas used by the oven burners was determined from the volume of the ovens, namely that 8,000 B.t.u. per hour of gas should be burned for each cubic foot of oven space. The actual inputs for the top

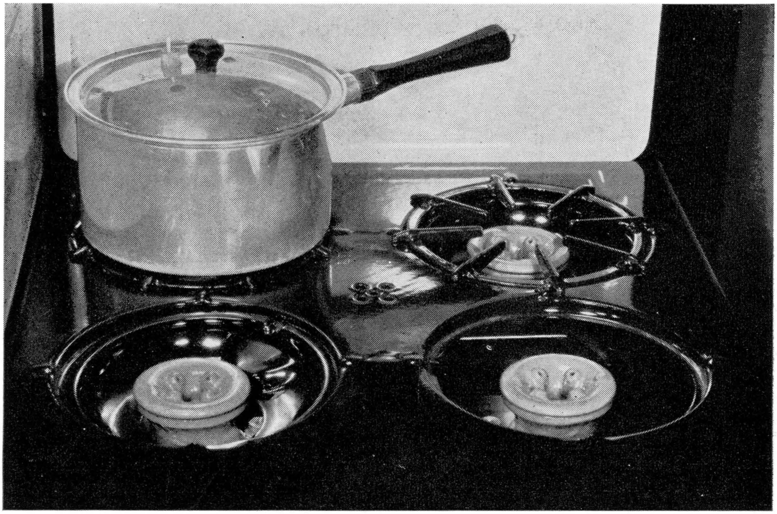

FIG. 3.—Cooking top M having enclosed top, slit type cast iron circular burner and burner bowls.

FIG. 4.—Cooking top N having enclosed top; die-cast slit type circular burners and burner bowls.

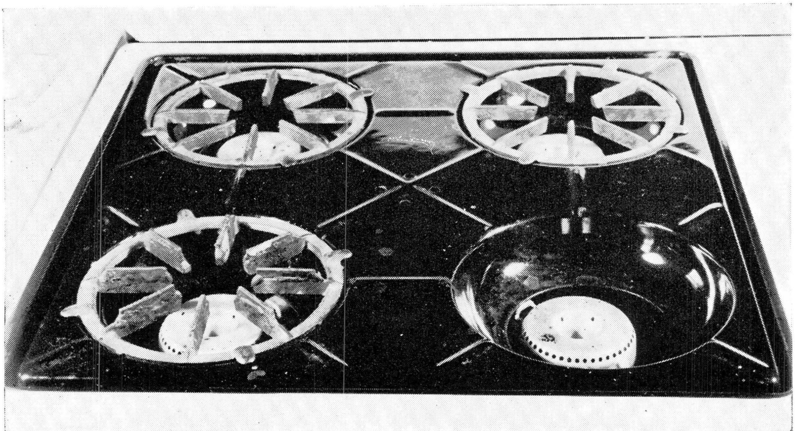

FIG. 5.—Cooking top O having enclosed top with burner bowls integral with the top. Cast iron circular burners. Note built-up grate prongs on front grate.

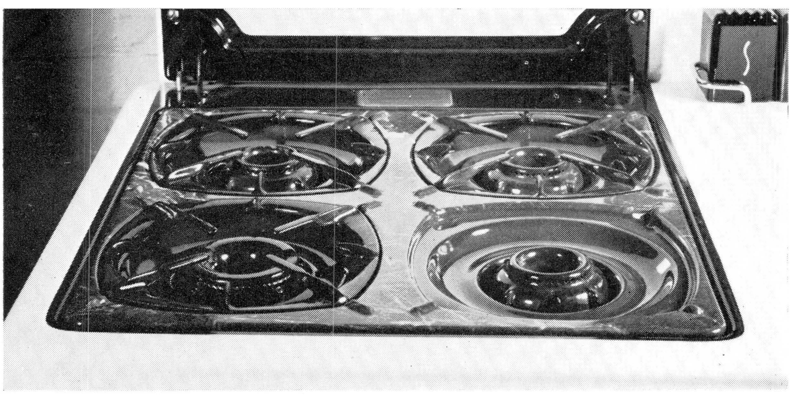

FIG. 6.—Cooking top P having burner bowls integral with enclosed top. Porcelain enameled cast iron burners. Simmer burner within center opening on all burners except left front giant burner.

burners are listed in Table 2. Each of the four burners on the cooking tops was adjusted for a different input or gas rate as follows: *Stove K*—6,000, 7,000, 11,000 B.t.u. per hour; *Stove L*—5,000, 6,000, 7,000, 9,000 B.t.u. per hour; *Stove M*—7,000, 8,000, 9,000, 10,000 B.t.u. per hour; *Stove N*—5,000, 6,000, 7,000, 9,000 B.t.u. per hour; *Stove O*—6,000, 7,000, 8,000, 9,000 B.t.u. per hour; and *Stove P*—all burners at 9,000 B.t.u. per hour. For all tests the normal operating gas pressure was seven inches of water.

TABLE 1.—*Burner capacities computed from port area and volume of oven on the basis of 20,000 B.t.u. per hour per square inch of port area and 8,000 B.t.u. per hour per cubic foot of volume.*

Stove	Type of burner	Volume of oven	Port area	Burner capacity: From port area	Burner capacity: From oven volume
		Cu. ft.	*Sq. in.*	*B.t.u./hr.*	*B.t.u./hr.*
K	Top regular	...	0.4922	9,844	.....
	Top simmer	...	0.0535	1,070	.....
	Oven	2.53	0.9774	19,548	20,240
L	Top rear regular	...	0.3572	7,144	.....
	Top front regular	...	0.3008	6,016	.....
	Top simmer	...	0.094	1,880	.....
	Oven	2.41	0.9993	19,986	19,256
M	Top	...	0.4535	9,070	.....
	Oven	2.07	1.156	23,120	16,560
N	Top	...	0.3068	6,137	.....
	Oven	2.47	1.209	24,180	19,736
O	Top	...	0.4277	8,554	.....
	Oven	1.97	1.645	32,900	15,776
P	Top giant	...	0.4140	8,280	.....
	Top regular	...	0.2760	5,520	.....
	Top simmer	...	0.1435	2,870	.....
	Oven	2.40	0.615	12,300	19,200

ANALYSES FOR EXCESSIVE CARBON MONOXIDE

Following the same procedure as described in Research Bulletin 86, samples of the combustion products were collected for each burner on all the stoves except stove P.[1] The results for the analyses of the combustion products for the cooking tops are given in Table 2. For a burner to be considered as producing no carbon monoxide, the American Gas Association Testing Laboratory requires that the percentage of CO in the combustion products shall not be greater than 0.08, on an air-free basis. Applying this requirement to these cooking tops it is evident that stove L was the only one that was satisfactory for all the burner inputs tested.

In attempting to determine the cause of the excessive carbon monoxide, stove K should be considered first because its surface burners were tested under so many varying conditions that the results obtained helped in the analysis of stoves M, N, and O. The fact that stove K was producing excessive CO became evident during efficiency tests with a gas rate of 11 cubic feet per hour at normal pressure. Analyses of the combustion products showed them to be heavily laden with CO. In Table 1 it is evident that the burner had a designed capacity for at least 10,900 B.t.u. per hour and since most burners will consume satisfactorily a quantity of gas greater than the designed capacity, another cause than an overloading of the burner was sought. It appeared that there was a deficiency of air to complete the combustion so when some of the samples were collected, the collecting hood was raised from the stove. In other tests the fire-bowl was removed. Samples were also taken for various rates of burning the gas.

[1] Stove P was not tested completely since it was a new model of a stove previously tested and our primary interest was in its oven.

TABLE 2.—*Analysis of combustion products from cooking-top burners.*

Cooking top	Gas input	Operating pressure	CO_2 air-free	CO air-free	Excess air	Reference number (see below)
	B.t.u./hr.	*In. water*	*P.ct.*	*P.ct.*	*P.ct.*	
K	11,000	8.75	12.00	0.584	54.2	3
	11,000	8.75	10.30	2.008	57.4	2
	11,000	8.75	9.05	4.200	57.4	1
	11,000	7.00	8.29	2.238	54.5	1
	9,000	8.75	8.35	3.145	60.0	1
	9,000	8.75	9.14	3.950	60.0	1
	9,000	8.75	10.94	1.780	59.5	4
	9,000	8.75	12.70	0.212	42.1	5
	9,000	8.75	10.52	3.065	42.7	1
	9,000	8.75	12.54	2.475	61.8	1
	9,000	8.75	10.00	1.970	59.7	6
	9,000	7.00	13.42	0.117	40.5	5
	9,000	7.00	12.54	0.532	50.9	1
	7,000	8.75	13.13	0.114	62.5	2
	7,000	8.75	13.32	0.056	48.4	1
	7,000	8.75	12.10	0.375	38.0	1
	7,000	8.75	14.60	0.000	66.4	1
	7,000	8.75	11.60	0.535	44.7	.
	7,000	8.75	9.45	1.633	92.8	7
	7,000	7.00	11.50	0.077	56.4	.
	6,000	8.75	13.30	0.266	45.0	1
	6,000	8.75	13.73	0.000	69.1	2
	6,000	8.75	12.70	0.050	50.6	1
	6,000	8.75	13.20	0.040	40.7	1
	6,000	8.75	11.98	0.089	60.5	8
	6,000	8.75	11.98	0.835	43.8	1
L	9,000	8.75	12.60	0.040	60.3	1
	9,000	7.00	13.60	0.009	65.0	1
	7,000	8.75	13.60	0.037	65.0	1
	7,000	7.00	11.32	0.022	70.7	1
	6,000	8.75	14.00	0.024	67.0	1
	6,000	7.00	11.19	0.006	71.1	1
	5,000	8.75	15.11	0.000	72.3	1
	5,000	7.00	11.18	0.000	77.0	1
M	10,000	8.75	12.64	0.692	27.2	.
	9,000	8.75	13.38	1.003	50.7	.
	8,000	8.75	14.75	0.006	58.0	.
	7,000	8.75	9.67	0.004	53.6	.
N	9,000	8.75	10.52	2,070	63.1	3
	9,000	7.00	10.78	0.906	63.8	3
	7,000	8.75	12.20	0.034	55.2	1
	7,000	8.75	10.30	0.063	62.7	2
	7,000	8.75	12.08	0.057	63.2	3
	6,000	8.75	12.38	0.022	68.8	2
	5,000	8.75	11.70	0.076	71.4	3
	5,000	8.75	12.48	0.019	72.3	3
O	9,000	8.75	11.46	0.447	61.6	9
	9,000	7.00	14.38	0.143	69.9	10
	9,000	7.00	11.07	0.368	69.6	9
	8,000	8.75	10.92	0.177	69.5	9
	8,000	8.75	10.98	0.161	74.6	9
	7,000	8.75	11.14	0.013	69.6	9
	6,000	8.75	11.20	0.000	64.8	9
	6,000	7.00	11.22	1.975	68.6	12
	6,000	7.00	11.10	4.550	71.5	11

1. Hood resting on cooking top.
2. Hood raised on ¼-inch blocks.
3. Hood raised on ⅜-inch blocks.
4. Hood on ¼-inch blocks, burner adjusted for maximum primary air.
5. Burner bowl removed, hood on stove.
6. Yellow flame from burner.
7. Sample taken around bottom of pan, no hood.
8. Hood on ⅜-inch blocks, no fire bowl, grate from stove M.
9. Built-up grate, hood on ⅜-inch blocks.
10. Hood on ⅜-inch blocks, grate from stove M.
11. Hood on $^{3}/_{16}$-inch blocks, regular grate.
12. Hood on ⅜-inch blocks, regular grate.

It will be observed that for a gas rate of 6 cubic feet per hour at normal pressure, excessive CO was produced on stove O. The same type of smothering was evident as for stove K. As an experiment, the grates were built up by welding on to each prong a strip of metal 3/16 inch high. For the built-up grate the analysis of combustion products was satisfactory for gas rates of 6 and 7 cubic feet per hour but unsatisfactory for higher gas rates. While a gas rate of 8 cubic feet per hour adjusted at normal pressure and operated at 1.25 normal pressure was unsatisfactory, it would have been satisfactory at normal pressure as indicated by the results for a gas rate of 7 cubic feet per hour at 1.25 normal pressure.[2] For stoves M and N the appearance of the flames at 9 and 10 cubic feet per hour showed that this gas rate was unsatisfactory. For these two stoves the excessive CO was due to the inability of the burners to handle properly higher gas rates than 8 cubic feet per hour. Neither burner was designed to take care of gas inputs for natural gas higher than those shown in Table 1.

The percentages of excess air shown in Table 2 were determined from the percentages of oxygen in the samples of combustion products.

The combustion products from ovens K, L, M, N, and O were analyzed for CO and the amount of CO air-free was found to be less than 0.08 per cent.

COOKING TOP TESTS

Cooking-top burner efficiency.—No efficiencies were determined for gas inputs that would produce CO. This is in contrast to the procedure used in the previous study where the standard gas rate was 9,000 B.t.u. per hour. The efficiencies for all cooking tops are listed in Table 3. This table is a comparison of the efficiencies for the various types of burners and adds to the data already published.

The effect upon efficiency of burners being off-center with respect to the burner bowl and grate was studied on stove O. When received, all of the burners on stoves M, N, and O were off-center. The burners on M were left unchanged, those on N were rebuilt in the stove so that they became centered, and on stove O the two burners on the left were adjusted so that they became centered while the two burners on the right were made more off-center. Briefly, the results showed that the efficiency of off-center burners was about 1 per cent lower than for centered burners for all pans except 7 and 8, where the decrease amounted to not more than 4 per cent. It seems that as far as efficiency is concerned, the centering of the burner is not of vital importance. From the construction point of view it does indicate poor assembling of parts.

The effect of increasing the distance between the burner and the top of the grate is shown by the decrease in efficiency of cooking top N for a gas input of 6,000 B.t.u. per hour. It is especially noticeable for the smaller pans.

---

[2] A gas cock adjusted to deliver 7 cubic feet per hour at 7 inches of water pressure would deliver 7.84 cubic feet per hour if the pressure were raised to 8.75 inches of water.

TABLE 3.—*Percentage efficiency for surface burners operating at normal pressure (7 inches of water).*

Type	Input	Distance between burner and top of grate	Thermal efficiency								
			Pan 1	Pan 2	Pan 3	Pan 4	Pan 5	Pan 6	Pan 7	Pan 8	Av.
	B.t.u./hr.	*In.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
K	6,000	1⅜	38.6	40.3	38.2	44.3	37.7	45.4	29.0	33.2	38.4
	7,000	1⅜	36.5	41.5	38.6	42.0	36.7	45.3	27.2	23.9	36.4
	9,000	1⅜	38.9	39.2	39.7	37.8	36.0	41.8	32.1	27.8	36.6
L	5,000	1⅜	39.9	40.8	42.4	46.4	45.5	47.2	39.0	37.3	42.3
	6,000	1⅜	39.0	42.7	43.7	45.7	44.0	44.5	39.0	32.4	41.4
	7,000	1⅜	38.2	37.6	39.4	41.0	39.5	38.2	27.9	27.7	36.2
	9,000	1⅜	34.0	35.7	37.8	41.0	36.3	35.6	27.6	26.8	34.3
M	7,000	⅞	42.3	48.2	46.3	50.3	43.0	50.6	35.8	27.6	43.0
	8,000	⅞	38.9	43.6	45.1	49.4	47.3	48.4	36.0	27.2	42.0
N	5,000	1⅜	44.7	46.6	45.6	49.7	45.6	50.4	33.1	27.3	42.9
	6,000	1⅜	42.2	43.8	44.2	47.0	41.9	48.2	33.0	28.0	41.0
	6,000	2	37.6	...	...	44.4	...	...	24.1	18.1	...
	7,000	1⅝	39.7	42.3	41.6	44.6	39.6	44.8	27.7	21.5	37.7
O[1]	6,000	1½	45.6	47.0	45.8	55.3	46.8	52.3	40.4	34.0	45.3
	7,000	1½	44.1	46.0	46.1	50.3	45.5	51.9	39.5	33.0	44.6
P	9,000	⅝	44.8	47.5	46.2	51.0	45.0	53.7	45.0	38.4	46.4

[1] Rebuilt grate used for efficiency tests.

Automatic lighters.—The requirement that a satisfactory automatic lighter on a domestic gas stove must meet is that the burner flame must ignite within four seconds after the gas is turned on or re-ignite within four seconds after the flame is blown out during twenty-five successive trials when the operating pressure has been reduced to half normal pressure.

In terms of the accepted lighter tests, stove N was the only one that had a satisfactory lighter. The lighter on this stove functioned correctly at half-normal pressure. The burners on stove K would ignite at normal pressure but would not always relight. At half-normal pressure they did not function correctly. Three of the burners on stove L were satisfactory at normal pressure, but would not light at half-normal pressure. The fourth burner did not light in five successive trials of five seconds each at normal, half-normal, and one-and-one-quarter-normal pressure. The rear burners on stove M were satisfactory at normal pressure but unsatisfactory at half-normal pressure. The front burners would not ignite at all. The results for stove O were similar to the others. None of these lighters, except N, could be considered as satisfactory.

It was found for two of the stoves that the lighter was improved by increasing the size of the lighter port in the burner. This allowed more gas to enter the lighter tube and apparently the velocity of the issuing gas was increased enough to carry the gas to the pilot flame. However, it was found that what worked in one case might not work in another. In all fairness it should be pointed out that these tests were conducted on only one stove out of the many manufactured by a company and whereas these lighters were unsatisfactory it cannot be concluded that all of the stoves equipped with the same type of lighter would have faulty automatic lighters. However, since the stoves were chosen from open stock, they were considered as representing the other stoves of the same model.

Since the automatic lighter was considered only as a convenience feature and not as a necessity, the problem was not investigated further because of the desire to spend most of the time on the study of ovens.

OVEN TESTS

Check on thermostat calibration.—With a dial setting of 400 as the point at which the dial reading should agree with the average oven temperature, ovens K, M, and O were considered as satisfactory since the temperatures were 400.6°, 401.7°, and 398.4° F. respectively. The dials on ovens L, N, and P were reset because for dial setting 400 the actual temperatures were 393.5°, 430°, and 451.6° F. respectively. These tests

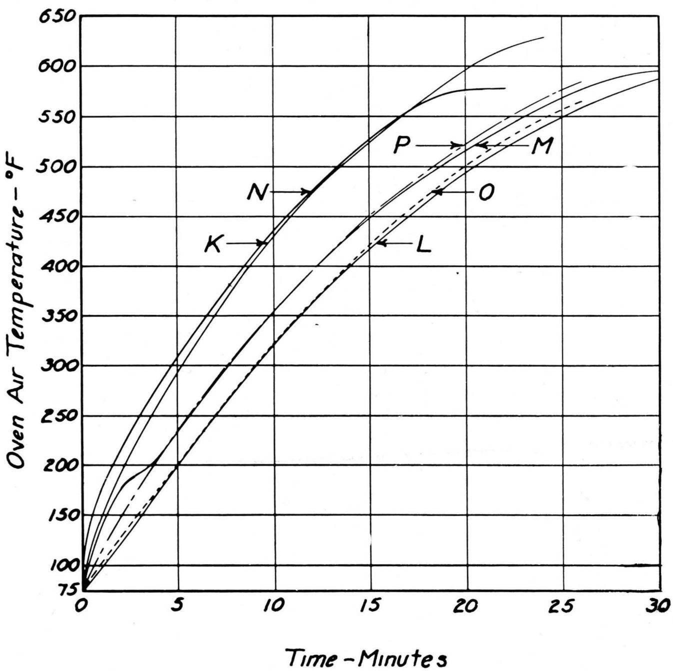

FIG. 7.—The time necessary to heat ovens K—P to various temperatures.

represented the ovens as the stoves were received from the factory. After the dials were adjusted so that there was agreement at 400 to within ± 2 degrees, average temperatures were obtained for dial settings from 250 to 500 or 550 by steps of 50. The results are tabulated in Table 4. In this table the temperatures are given to ±0.5 degree. When the dials on ovens K, L, N, and O were set a back-lash in the dial mechanism was noticed. This could account for a variation of at least 5 degrees in agreement when settings were repeated. However, for actual cooking this slight back-lash would not be serious.

Rate of heating.—Curves showing the relation between the time and the energy necessary to heat the respective ovens to 500° F. are presented in Figures 7, 8, and 9. All of the ovens except L satisfied the American Gas Association requirement, namely, that the oven temperature would increase from room temperature to 500° F. at an average rate of at least 21.5 degrees per minute. These curves furnish comparisons of the rate of heating because all of the burners were adjusted on the same basis,

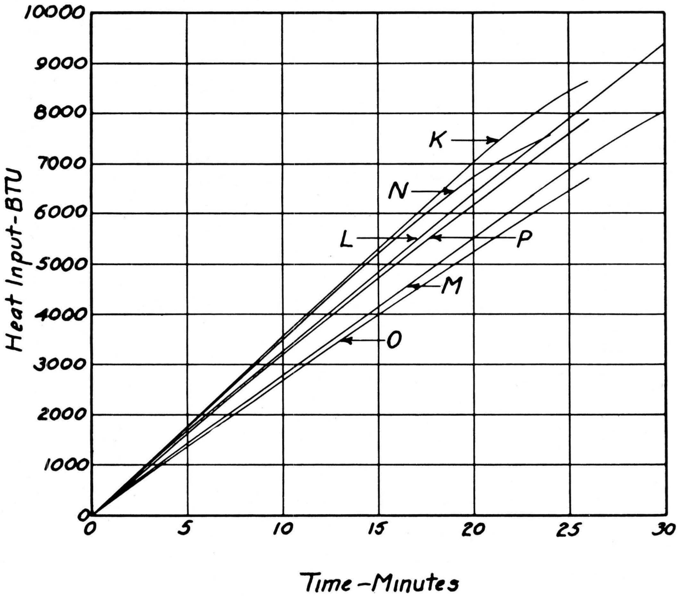

FIG. 8.—The time rate of consumption of heat of ovens K—P.

namely 8,000 B.t.u. per hour input for each cubic foot of oven space. In each case the thermostat was set at least to the 550 mark so that the curves represent the minimum time to preheat to 500° F.

Rate of cooling.—One method of representing the heat-retaining quality of an oven is to show its rate of cooling. The results are shown in Figure 10. In obtaining data for the cooling curves, it must be remembered that the ovens are not in steady-state conditions; hence the cooling curves cannot be compared directly with the heat-loss curves. However, it is interesting to note that as far as general grouping is concerned the relationships in the two sets of curves are similar.

Empty-oven heat loss, internal temperature distribution, and surface temperatures.—The heat-loss curves shown in Figure 11 give the quantitative heat-retaining qualities of the ovens. That is, the data represented by

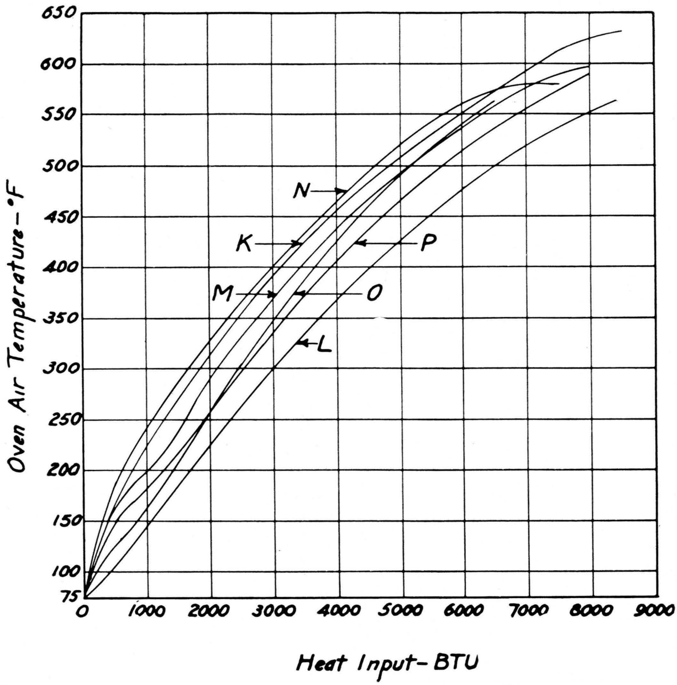

FIG. 9.—The quantity of heat necessary to raise ovens K—P from room temperature to temperatures as high as 550° F.

the graphs show the heat necessary to maintain an empty oven at various temperatures. At the same time that the heat-loss data were obtained for oven temperatures of 300°, 400°, and 500° F., heat distribution in the oven was determined by measuring the temperature at fifteen locations in the oven. The thermocouples were distributed on lower, middle, and upper planes with five couples to a plane.

The internal air temperatures are listed in Table 5. The exterior oven surfaces were divided into areas in the same manner as described in

TABLE 4.—*Average oven temperatures for various dial settings.*

Dial	Average oven temperature in degrees Fahrenheit for:							
setting	K	L	M	M′	M″	N	O	P
225	...	...	...	...	...	...	...	230
250	302	285	301	231	223	292	342	247
300	311	298	301	284	287	299	344	301
350	337	343	346	...	348	354	348	...
400	401	398	400	402	403	410	398	403
450	461	458	463	...	461	465	447	467
500	517	540	519	...	...	520	493	521
550	574	606	...	...	539	574	552	...

Note: M is oven equipped with regular burner. M′ is oven M equipped with special burner (36 ports closed). M″ is oven M with all insulation removed and equipped with special burner.

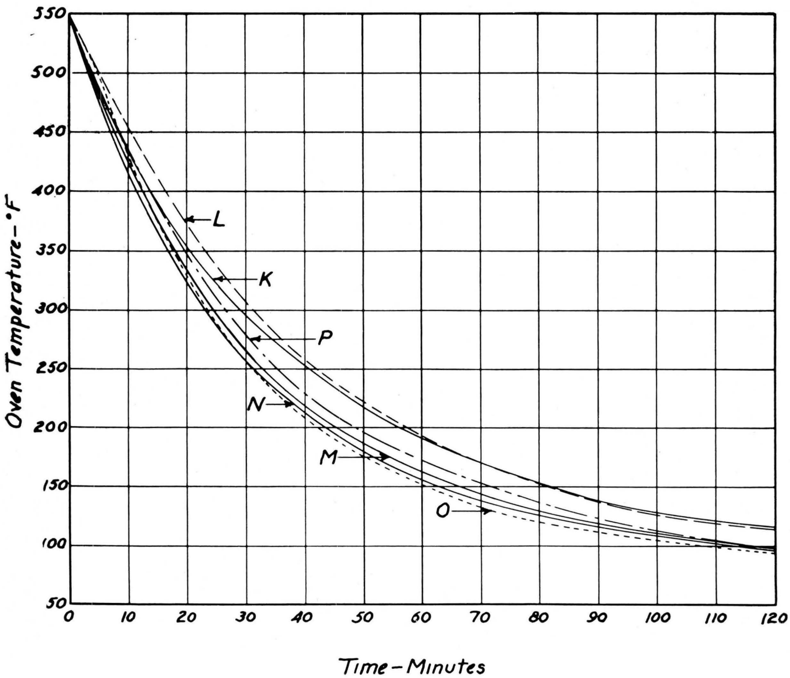

FIG. 10.—Time rate of cooling of ovens K—P from 550° F. to 115 or 100° F.

Research Bulletin 86, and during the heat-loss tests temperatures were measured at the center of each area. From these data the average temperatures for the top, sidewalls, back, oven door, and broiler door were determined. These temperatures are listed in Table 6.

A more detailed study was made of oven M. This oven was chosen because it had more external surface exposed and it was also easy to remove the inner linings so that the insulation could be taken out. It was desired to determine what effect burner design, insulation, and door cracks had upon the performance of the oven and finally to find out how much heat was actually lost from the vent. Heat loss and calibration tests were first performed. The thermostat check has been given in Table 4. After the calibration with burner as received from the manufacturer, 36 ports were closed and it will be noticed from Table 6 that the performance was improved inasmuch as a lower oven temperature could be maintained. With this special burner, and the thermostat dial at 250, the loaded oven test was performed. It was found that the temperature was much lower with a heavy load of sand in the oven. The relation between temperature and time when the oven was loaded is shown in Figure 12. The slight dip in the curve after the 10-minute mark shows the slight cooling after the thermostat had turned off. The sand was removed at the end of 4

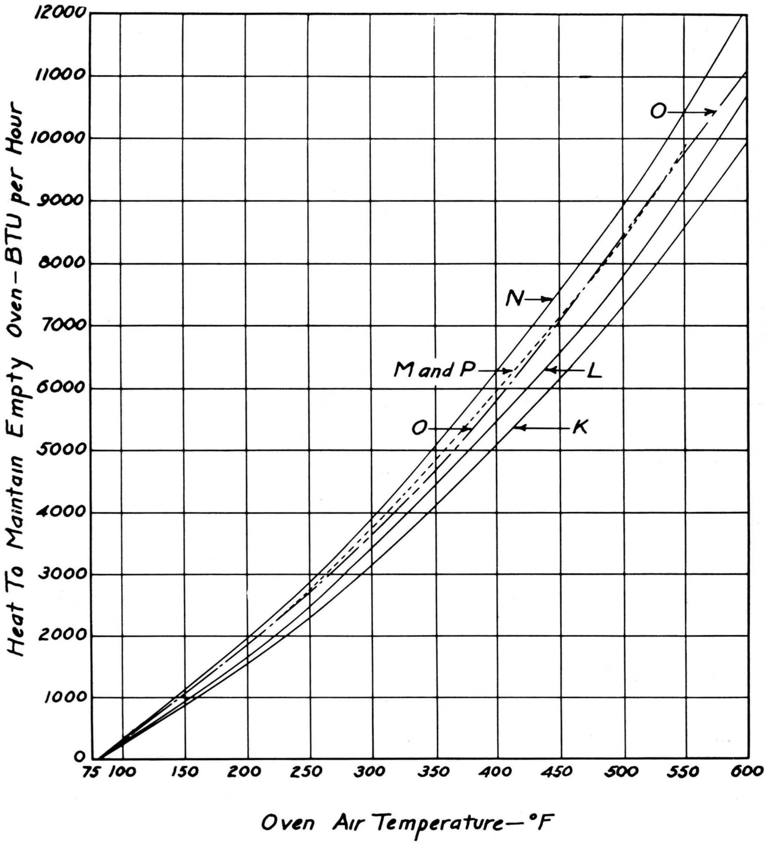

FIG. 11.—The heat necessary to maintain ovens K—P when empty at various temperatures from 75°-600° F.

hours and 45 minutes and the empty oven was allowed to come to the steady state, where the temperature became 245.6° F.

Curves showing the ordinary heat loss, the heat loss when the crack around the oven door was filled with mineral wool, and the heat loss of the oven when all of the insulation was removed are given in Figure 13.

Finally, it was felt that it would be worth while to know what percentage of the total loss could be attributed to the loss from the vent. The method of finding this loss is described in the following section.

Calorimetric determination of vent loss.—The apparatus for measuring the vent loss is shown in Figure 14. It consists of a Junkers flow calorimeter with an insuulated close-fitting stack in place of the regular Bunsen burner. The stack was secured to the flue collar at the oven-flue outlet. For all of the heat-loss tests the check-draft holes in the bottom of the

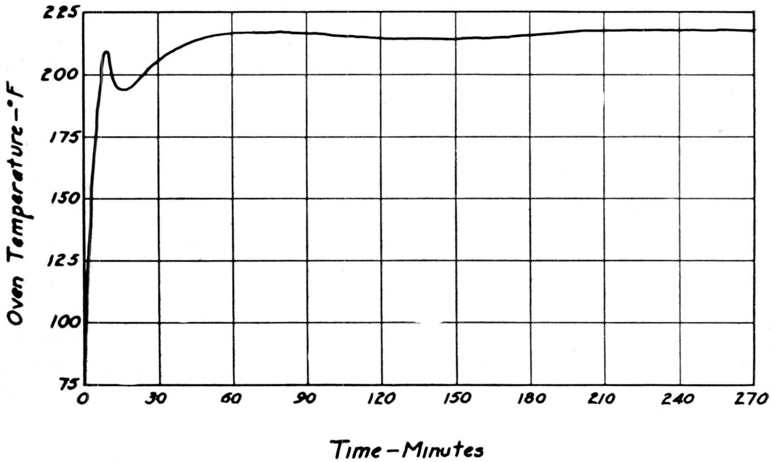

FIG. 12.—The relation of oven temperature to time when a load of wet Ottawa sand was used in oven M.

flue collar were plugged with corks. Ordinary asbestos-cell pipe covering was used as insulation around the connecting pipe. The insulation was about one inch thick and while it might have been better to have a thicker insulation, this insulation proved satisfactory since the flue collar

TABLE 5.—*Average air temperatures for lower, middle, and upper planes of ovens K—O.*

Oven	Dial setting	Lower plane	Middle plane	Upper plane
		° F.	° F.	° F.
K	300	303.0	301.4	304.2
	400	401.9	399.8	402.2
	500	502.4	499.0	500.2
L	300	305.4	299.6	303.9
	400	399.9	398.4	402.0
	500	500.3	495.5	499.5
M	300	314.1	306.5	310.7
	400	409.3	405.9	413.0
	500	503.7	500.4	507.8
M′	300	317.2	315.3	322.3
	400	404.2	398.7	403.6
	500	504.9	500.4	508.0
M″	300	303.9	300.3	304.4
	400	403.0	402.5	411.9
	500	506.3	500.1	506.1
N	300	304.2	300.6	302.7
	400	406.7	401.0	403.8
	500	505.4	501.7	502.9
O	400	397.0	398.3	404.5
	500	501.2	498.0	507.3

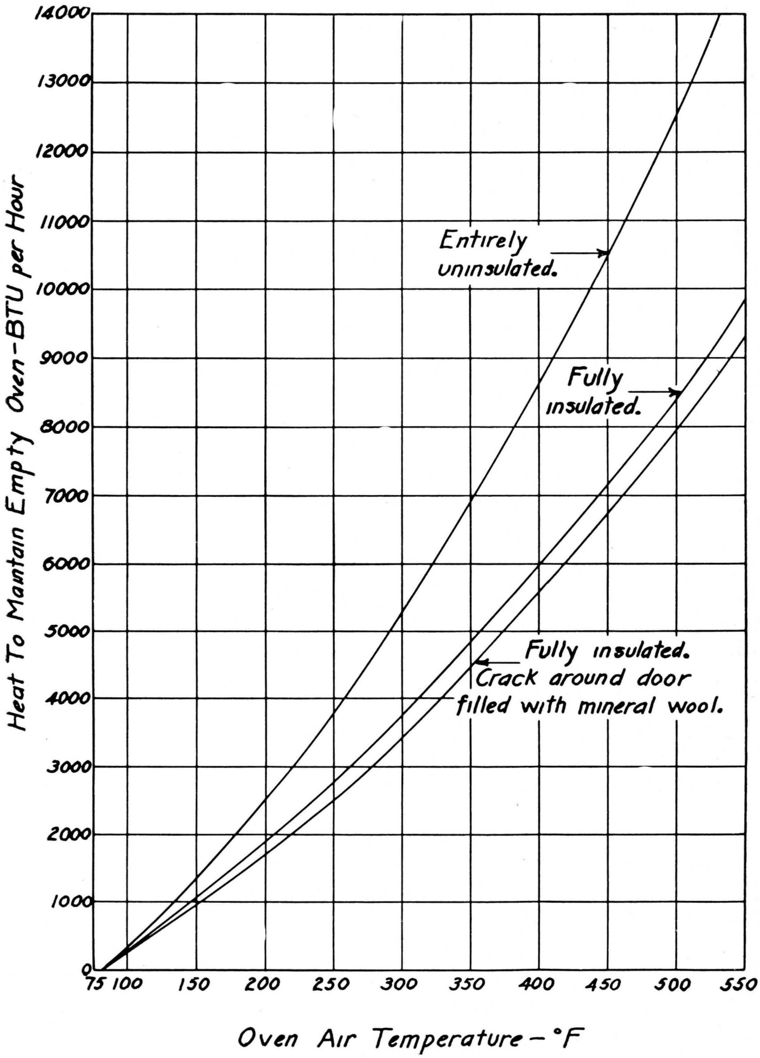

FIG. 13.—The heat necessary to maintain oven M at various temperatures as high as 550° F. for insulated and uninsulated oven conditions.

itself was uninsulated. The flue collar was considered as being a part of the oven.

The inlet and outlet water temperatures were measured by Centigrade thermometers graduated to 0.1 degree, while the exhaust-temperature thermometer was graduated in 1.0-degree (C.) divisions. Inlet water

TABLE 6.—*Average exterior surface temperatures for oven K—O for oven air temperatures of 300°, 400°, and 500° F.*

Area	Oven air temp.	Average temperatures for K	L	M	M′	M″	N	O
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
Top	300	111.4	89.0	117.3	114.1	154.8	105.2	....
	400	125.2	102.2	137.9	126.3	179.5	123.0	162.0
	500	146.9	115.2	156.1	143.7	222.3	142.0	180.2
Side (oven section)	300	118.4	110.7	126.8	129.5	165.9	113.8	....
	400	137.8	126.4	150.9	146.5	203.2	136.2	158.6
	500	160.4	144.2	170.0	175.3	240.7	156.2	182.8
Side (broiler section)	300	110.6	....	110.3	115.0	133.8	110.5	....
	400	135.9	....	129.3	130.3	162.1	132.0	145.5
	500	163.5	....	146.0	149.4	198.0	145.8	169.9
Back (oven section)	300	138.2	105.0	121.9	123.4	162.4	129.6	....
	400	168.8	128.0	152.1	144.2	191.3	158.2	175.8
	500	196.4	148.4	168.6	168.9	239.4	183.5	196.3
Back (broiler section)	300	124.2	....	116.7	118.4	143.5	113.0	....
	400	160.0	....	140.2	137.4	180.4	132.8	145.6
	500	193.5	....	153.6	158.4	229.6	151.0	166.0
Oven door	300	124.3	114.0	133.4	124.5	162.2	128.4	....
	400	143.8	137.9	154.1	139.6	197.2	159.0	169.1
	500	169.4	158.2	179.0	163.5	248.3	192.2	194.9
Rim around oven door	300	137.7	134.5	....	....	....	152.0	....
	400	167.4	168.8	....	....	....	197.0	197.3
	500	199.7	201.5	....	....	....	243.0	228.9
Broiler door	300	116.0	....	121.1	122.2	141.4	124.6	....
	400	142.4	....	122.0	136.6	160.4	150.4	146.1
	500	168.6	....	158.2	156.8	194.2	169.3	170.5

temperatures were regulated by mixing hot and cold water from the taps. Room temperature was kept as nearly constant at 80° F. as possible and since the total heat loss from the oven was calculated in terms of room temperature as the reference base, the exhaust temperature from the calorimeter had to be at room temperature also.

Before the calorimeter was used for the vent-loss determination, it was necessary to ascertain whether the performance of the oven burner was affected by the addition of the calorimeter to the flue outlet either as stack action or as a retarding factor on the exhaust gases. To check the effect of the calorimeter, samples of the combustion products were taken with the calorimeter connected and disconnected from the oven at time intervals as close together as possible between samples. This flue gas was analyzed for CO_2 and O_2 and the percentages of CO_2 were calculated on an air-free basis and compared for connected and disconnected calorimeter conditions. Volume differences of 0.02 cc. could be measured with the burette used in the Orsat apparatus. For all analyses, nitrogen was put in the manifold at the beginning of each test so that there would be no residual gas from previous tests. The results are given in Table 7. In Test 1 the check-draft holes were open but they were closed for all other tests. Oven temperatures were at the steady state for all tests. Considering the small amount of CO_2 and the large amount of O_2 in the

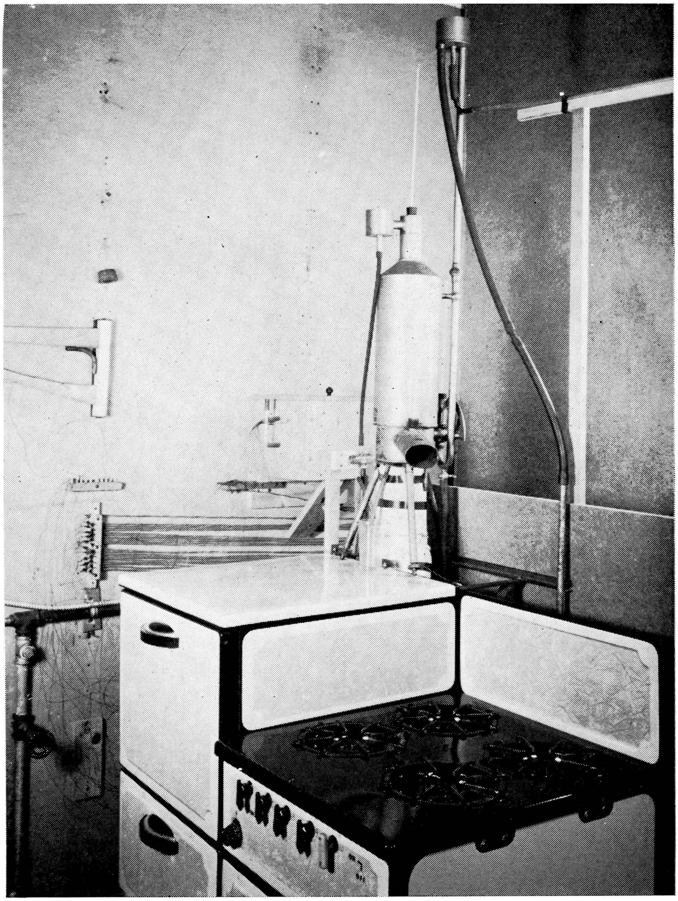

FIG. 14.—Apparatus for measuring heat loss from the vent of oven M.

sample, the values for percentage of CO_2 air-free were taken to be in good agreement, indicating that the calorimeter did not change combustion conditions.

TABLE 7.—*Flue analysis of combustion products from oven M with calorimeter connected and disconnected.*

Test	Calorimeter exhaust temp.	Room temp.	Oven temp.	Calorimeter connected			Calorimeter disconnected		
				CO_2	O_2	CO_2 air-free	CO_2	O_2	CO_2 air-free
	° F.	° F.	° F.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.
1	77.9	79.7	300	1.020	19.10	11.71	0.940	19.18	11.32
2	79.7	79.0	300	1.160	18.72	11.05	1.080	18.85	11.02
3	80.6	81.0	400	1,965	17.45	11.90	1.750	17.83	11.90
4	80.0	80.0	300	0.868	19.21	10.60	0.795	19.38	10.73
5	80.0	80.0	300	1.072	18.90	11.18	0.992	19.07	11.15

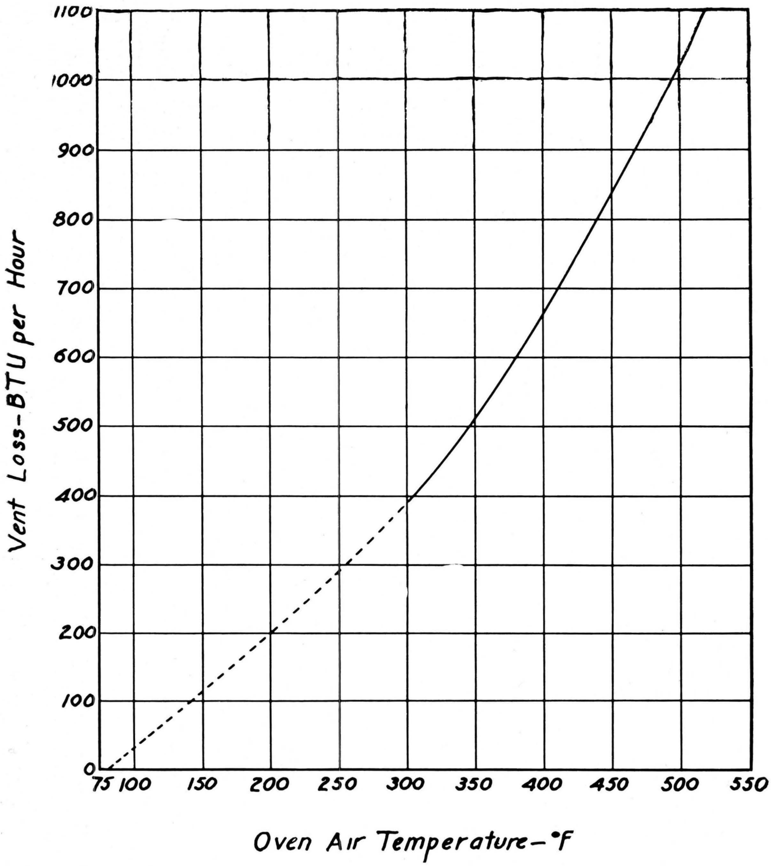

Fig. 15.—The relation of vent loss in B.t.u. per hour to oven air temperature for an average exhaust temperature of 79.5° F.

The vent loss for oven M in B.t.u. per hour plotted against oven-air temperature is shown in Figure 15. The values of the vent loss at 300°, 350°, 400°, 450°, and 500° F. were determined by averaging the results obtained from the calorimeter tests. The average exhaust temperature was 79.5° F. With the total heat loss of the oven for various oven air temperatures known, the percentage of vent loss was calculated. The percentage of vent loss increased from 11.1 at 300° F. to 12.6 per cent at 500° F., the average for the range 300°-500° F. being 11.9 per cent. With reference to Figure 15 it is of interest to note its similarity in shape to the heat-loss curve for oven M in Figure 11.

DISCUSSION OF RESULTS

Combustion products.—The data for stove K indicate that some relation exists between the burner bowl and grate, as used on the stove, and the production of excessive carbon monoxide. While the percentage of CO was greater for high gas rates than for low, the gas input was not decreased enough to make the burner assembly consistently satisfactory. For gas inputs less than 6,000 B.t.u. per hour the rate of heating would be too slow. It is the author's opinion that the grate prongs were too nearly on the same level with the stove top, and that with pans having a diameter similar to that of the grate the products of combustion could not escape and consequently there was a smothering of the flame. With the grate and burner bowl as built in the cooking top, no change could be found that would give results that would make cooking top K satisfactory.

For cooking tops M and N gas rates of 9,000 B.t.u. per hour or greater produced excessive CO. From the appearance of the flame it was evident that satisfactory primary air adjustments could not be made for gas rates of 9,000 B.t.u. per hour or greater. At these gas rates the flames were either irregular and wavering or else they blew from the ports.

The remodeling of the grate on cooking top O has already been mentioned. The addition of 3/16-inch in height to the grate prongs was sufficient to make this burner assembly satisfactory for gas rates of 7,000 B.t.u. per hour or less (adjusted at normal pressure) when operated at 1.25 normal pressure. At higher gas rates the flames blew from the ports.

Thermal efficiency of cooking top.—These cooking tops show an increased efficiency over the cooking tops previously tested. The highest efficiency was obtained with top P where the burner was very close to the bottom of the pan. Next in order was cooking top M. All of these tests show the advantage of having light-weight but sturdy enclosed tops fitted with burner bowls and light-weight grates. The same conclusions regarding cooking tops as published in Research Bulletin 86 apply to these tops.

Automatic lighters.—The automatic-lighter tests showed that this part of the stove still needs improvement. Many times the lighters failed to work properly because the gas would ignite at the end of the lighter tube at the pilot, but the flame would not travel back through the tube to the burner. For the burner on stove L which would not light at 1.25 normal pressure (that is, absolute failure in automatic ignition) the trouble was traced to the lighter port in the burner. The position and angle at which the hole was drilled apparently directed the issuing gas in such a manner that free flow down the lighter tube was checked.

For all of the lighters that failed to function properly, no sure method was found that would insure successful lighting of the burner for at least 25 consecutive trials.

Ovens.—The results in Table 4 show the dependence of low oven temperatures upon low-capacity burners and insulation. It is evident from the data in Table 1 that the burner in oven M had more ports than necessary for the size of oven it was to heat. Consequently when the by-pass valve was regulated to give the minimum flame possible without extinguishing the flames there was still so much heat being delivered to the oven that the temperature would not go lower than 301° F. By plugging 36 ports and readjusting the by-pass valve to again produce the smallest flame possible, a temperature of 231° F. was attained. Note also how many excess ports were used on the burner in oven O by referring to both Table 1 and Table 4.

The data for M″ show how the oven-air temperature was further decreased by the removal of all insulation. It is apparent that the decrease was caused by the increased heat loss from the outer surfaces. Referring to Figure 11, suppose that the heat loss of oven M was decreased to a value lower than that of K by better insulation of the oven. It would then be found that the special burner of M″ would no longer be satisfactory because the minimum flame would now supply too much heat. It would again be necessary to plug more ports to decrease the heat input. Thus as the oven insulation is improved the burner must be redesigned. That is precisely what was done for oven P. The burner in this oven is an example of a design which meets the requirements of rapid preheating as shown in Figure 7 and also of maintaining low temperatures as shown in Table 4.

There is still a third factor that will lower the internal temperature of the oven, namely the effect of putting a cold substance in the oven. The thermostat which controls the oven temperature may be located in a place where it is only slightly affected by the cold load. Thus, while around the thermostat the temperature is such that the controls regulate the gas to give the temperature indicated on the dial, the actual temperatures around the load may be much lower. This is shown in Figure 12 where the oven temperature was 215°-218° F. with the dial set at 250. When the load was removed, the temperature for the empty oven finally rose to 245.6° F., where it remained.

Figures 10 and 11 show that ovens K and L had better heat-retaining qualities than the other ovens. The data given by the graph in Figure 11 are the most important because the actual heat loss in B.t.u. per hour for any oven-air temperature may be obtained from the curves. In connection with the graphs in Figure 11 it is of interest to note the various average surface temperatures given in Table 6. The top temperatures on oven L are not comparable with similar temperatures on the other ovens because the cooking-top burners were immediately above the oven and top temperatures were measured on the cover over the top burners. Also the broiler on stove L was separate from the oven burner; that is, it was a separate compartment opposite the cooking top. Surface temperatures on the sides and back were separated according to the area surrounding the oven and that surrounding the broiler. While these surface temperatures indicate the relative heat loss from the different parts of the oven, they do not give a complete picture of the entire heat-loss areas. This is evident from a comparison with Figure 11. For instance oven K had a lower heat loss than oven L, but the surface temperatures of oven L were lower than those of oven K, indicating that oven L was losing a great amount of heat at some place that was not measured. Likewise oven O can be compared with ovens M and N. Oven L was designated as a fresh-air oven; that is, openings were provided at the rear and bottom of the oven so that fresh air could enter. However, upon plugging these openings with cork it was found that the heat loss was decreased only by approximately 150 B.t.u. per hour. Thus these openings do not materially affect the heat-retaining qualities of the oven.

The average temperatures for the three planes in the oven as given in Table 5 show that the heat distribution was quite uniform. However, comparing individual temperatures with these average temperatures showed the following. For ovens K and L the center of the lower and middle planes was hotter than at the corners. For ovens M and M′ conditions were as follows: lower plane, cool spot at left front corner, warm spot at right rear corner; mid-plane, quite uniform; upper plane, cool spot at left rear corner, hot spot at center. For oven M″: lower plane, cool spot at left front corner; mid-plane, quite uniform; upper plane, cooler in rear, warm spot at center. For ovens N and O the temperatures were quite uniform on all three planes.

The effect of filling the crack around the oven door and removing all the insulation on oven M is evident in Figure 13. The change in surface temperatures is shown in Table 6. These data definitely show the advantage of insulating the oven.

The adaptation of the flow calorimeter as a means of measuring the quantity of heat lost from the oven vent was a method that was convenient and simple to operate. The accuracy that may be obtained would depend primarily upon the ability to read small changes in the temperature of the inlet and outlet water. Considering the thermometers used, a variation of 10 B.t.u. per hour in vent loss could be expected from the uncertainties in temperature readings beyond 0.1° C.

This study of heat losses from oven M showed that most of the heat was being transmitted through the side walls, top, and doors. Filling the crack around the door made very little difference in the heat-retaining quality of the oven. Thus, to improve the oven with regard to heat loss it would be necessary to improve the insulation of the side walls, top, and doors. While no data were obtained relative to the heat loss from the bottom of the oven, it was evident that considerable heat could escape there because it was covered only with the broiler drawer. It seems to the author that the heat loss from the present gas ovens is still rather high and that the oven should be better insulated so that the heat necessary to maintain the empty oven would be reduced to at least half the values shown in Figure 11.

CONCLUSIONS

From the detailed study of gas ranges, significant results have been obtained which may be expressed in the form of optimum requirements necessary to insure satisfactory performance for economical operation.

While the stoves were studied with natural gas as fuel, the results are applicable to manufactured and bottled gas because principles rather than individual stoves were studied.

Optimum requirements of the cooking top:

1. The top burners should be of the non-clog type and should have a thermal efficiency of 50 per cent when operated with a five-quart aluminum pan having a bottom diameter of 7½ inches.
2. The burners should have a wide heat spread so that a uniform heat distribution may be obtained with large utensils.
3. To insure high efficiency the cooking top should be the enclosed type having burner bowls as a part of the top. The top should be lightweight but sturdy. The grates should have as few prongs as necessary to support the pan and make contact with the top at only four points. Burners should be centered with respect to the burner bowls and grates.
4. The cooking top burner assemblies should produce no carbon monoxide.
5. To prevent crowding of large utensils, burners should be at least 10½ inches apart, center to center, when measured across the front of the stove and from front to back.
6. At least two of the burners should be equipped with wide-heat-spread simmer burners built in the center of the regular burner. It should be possible to maintain a low heat with these simmer burners.

Optimum requirements for ovens:

1. The oven burner should be capable of preheating the oven rapidly. A satisfactory heating rate would be one that would preheat the oven from room temperature to 500° F. in 15 minutes.
2. The oven burner should be capable of maintaining a constant temperature of 250° F. when the oven is empty.
3. The heat should be controlled by a thermostat that will maintain temperatures to within ± 2 degrees F. for each dial setting. There should be no backlash in the dial mechanism.
4. The oven should be well insulated so that the heat necessary to maintain the empty oven would not exceed 3,000 B.t.u. per hour at 400° F.
5. The heat distribution in the oven should be uniform. Temperature gradients between different points in the oven should not exceed 10 degrees F.
6. The oven door should be tightly fitted but should not be clamped to make a tight fit.
7. To prevent crowding when the oven is fully loaded with six loaves of bread the interior oven dimensions should be at least 16 inches wide, 14 inches high, and 19 inches deep. Sufficient rack spacing should be provided so that bread on the bottom rack will not touch the top rack nor will bread on the top rack touch the top of the oven.

[2½M]